

User's Guide for GOES-R XRS L2 Products

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21 May 2020

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1 Summary

The GOES X-Ray Sensor (XRS) measurements have been a crucial component of space weather operations since 1975, providing an accurate measurement of geo-effective X-ray irradiance from second-to-second real-time conditions to solar-cycle time scales (Garcia, 1994). XRS measurements are in two bandpass channels commonly referred to as the XRS-A (0.05-0.4 nm) and XRS-B (0.1-0.8 nm), both of which are in the soft X-ray portion of the electromagnetic spectrum.

The GOES-R XRS instrument provides irradiance ranges of more than 6 orders of magnitude by using two photodiode sets to cover overlapping portions of the irradiance range for the XRS-A channel and also for the XRS-B channel. XRS-A1 and XRS-B1 are larger Si diodes to measure low X-ray fluxes, and XRS-A2 and XRS-B2 are smaller, quadrant Si diodes to measure high X-ray fluxes, and to also provide approximate flare location on the solar disk. For each 1-s measurement, one of the A channels and one of the B channels are designated the primary channels depending on the measured irradiance and channel switching threshold. The XRS instrument is described in detail by Chamberlin et al. (2009).

On the GOES-R series satellites, XRS is part of the Extreme Ultraviolet and X-Ray Irradiance Sensors (EXIS). EXIS was designed and built by the Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado Boulder. The Level 1b (L1b) data consists of 1-second cadence soft X-ray irradiance measurements covering 0.05 to 0.4 nm and 0.1 to 0.8 nm integrated passbands. The Level 2 (L2) data consists of cleaned 1-s data and higher order products such as irradiance averages, flare event summaries, and flare location. The 1-minute integrated XRS-B irradiance is used for solar flare classifications, and is key for the NOAA Space Weather Prediction Center (SWPC) operations, allowing early warnings of major flares to be issued. Due to the Neupert effect (Neupert, 1968), the harder X-rays measured in XRS-A irradiance reach their maximum value in advance of the softer XRS-B X-rays, and the ratio of the XRS-A to -B irradiance has a variety of uses including the issuance of alerts by the SWPC forecasters, and the calculations of the flare temperature (Woods et al., 2008), and the derivation of the mean solar coronal temperature during non-flare conditions (Thomas et al., 1985; Garcia, 1994; White et al., 2005). This User’s Guide discusses the algorithms to generate the L2 data products.

Scientific quality XRS L1b and L2 netcdf datasets are produced by NOAA’s National Center for Environmental Information (NCEI) for XRS, and differ from the operational product used at SWPC in that they incorporate retrospective fixes for issues in the operational product and the data have been reprocessed from the start of the mission to the present date (See Section 2.1). Users are advised to use the science quality data XRS L2 data instead of the operational data. The science quality data directories have names which end in ”_science” and the file names have prefixes of ”sci”.

This User’s Guide gives details of the GOES-R XRS L2 algorithms (Machol et al., 2020). Users of the GOES-R XRS data are responsible for inspecting the data and understanding the known caveats prior to use. Data caveats are given in the GOES-R XRS Science Quality L2 Readme. Links to the science-quality XRS data, Readme’s, a User’s Guide, plots, responsivity data, and associated documentation can be found at <https://www.ngdc.noaa.gov/stp/satellite/goes-r.html>. Technical questions about this data can be sent to janet.machol@noaa.gov or courtney.peck@noaa.gov, while questions about data access should be sent to pamela.wyatt@noaa.gov.

2 XRS L2 Products Overview

XRS measures soft X-ray fluxes at 1-second cadence in the historical bandpasses 0.05 to 0.4 nm and 0.1 to 0.8 nm, corresponding to Channel A and B, respectively, on the XRS instrument. Each channel has two irradiance sensors to capture the full dynamic range of the solar X-ray irradiance, where ”1” denotes low-irradiance sensor and ”2” is for the high-irradiance sensor. This numbering is utilized in the variable naming convention where, for example, ”xrsa2_flux” corresponds to the irradiance in Channel A on the high irradiance sensor. The flag ”xrsa_primary_chan” indicates whether XRS-A1 or XRS-A2 provides the primary irradiance values. The current thresholds for switching the primary channels are 10^{-5} W m⁻² for Channel A and 10^{-4} W m⁻² for Channel B. We note that the terms irradiance and flux are used interchangeably in this document.

The six L2 products for XRS are listed in Table 1.

Table 1: Summary of XRS L2 Products

Product	Name	Description
1s fluxes	flx1s	XRS irradiances at 1-s cadence
1-min fluxes	avg1m	XRS irradiances at 1-min cadence
flare summary	flsum	flare detection flags such as start and peak
flare detection*	fldet	flare detection status for every minute
flare location	flloc	flare location
daily background	bkd1d	daily background and daily averages

* Most users should use the the flare summary instead of the flare detection product. See warning in Section 5.

2.1 Science Quality versus Operational XRS Data

The science quality L2 data products differ from the operational L2 products used in operations at SWPC in that they incorporate retrospective fixes that are not in the operational data as well as some recovered data that was missing in the real-time operational products. Also, this dataset uses the most recent calibrations. The Science-Quality L2 data products are created from the Science Quality L1b data. The operational L1b and L2 data, especially from the earlier dates, contain significant issues that are not retroactively corrected, and therefore should be used with great caution and not for scientific analysis.

2.2 Flare Magnitudes

A notable change between the GOES-R and previous GOES data is that the GOES-R XRS irradiances are provided in true physical units of W m^{-2} . The operational data prior to GOES-16 had scaling factors applied by SWPC so as to adjust the GOES 8-15 irradiances to match fluxes from GOES-7. The flare index was based on the operational irradiances, but to get true irradiances from the operational data, the scaling factors of 0.85 (for the XRS-A channel) and 0.7 (for the XRS-B channel) applied to GOES 8-15 had to be removed. There are no such scaling factors in the GOES-R XRS data; the provided irradiances are in true physical units.

The magnitude of a flare is defined by SWPC with a flare index that is based on the 1-minute average of the GOES operational irradiance in the XRS-B channel at the peak of the flare. Flare indices are denoted by a letter and a number based on the log 10 peak irradiance of the flare (X: 10^{-4} W m^{-2} , M: 10^{-5} W m^{-2} , C: 10^{-6} W m^{-2} , B: 10^{-7} W m^{-2} , and A: 10^{-8} W m^{-2}). For instance, an M5 index is defined for a $5 \times 10^{-5} \text{ W m}^{-2}$ peak irradiance, and an X2.5 index is defined as an irradiance level of $2.5 \times 10^{-4} \text{ W m}^{-2}$ peak irradiance. Because of the SWPC scaling factors in the pre-GOES-R data, flare indices for the earlier satellites were based on irradiances that were reported as 42% ($1.0/0.7$) smaller than for GOES-R (e.g., an X2.5 class flare reported operationally for GOES-15 will be an X3.6 class flare for GOES-R). Two XRS Level 2 (L2) products useful for flare detection are the event detection and event summary which provide flare peak irradiances, indices, and times.

A related note is that science-quality GOES 13-15 XRS reprocessed L1b and L2 data are now available. In this GOES 13-15 reprocessed data, the irradiances are provided in physical units (i.e., without the SWPC scaling factors) to match the GOES-R data. This earlier data is available from the GOES 8-15 tab at <https://www.ngdc.noaa.gov/stp/satellite/goes-r.html>.

2.3 XRS Response Functions

The responsivity for the GOES-16 XRS channels is shown in Figure 1. The response functions for all satellites, plots, a Readme, and an IDL code to read the data are available from the documents link at <https://www.ngdc.noaa.gov/stp/satellite/goes-r.html>.

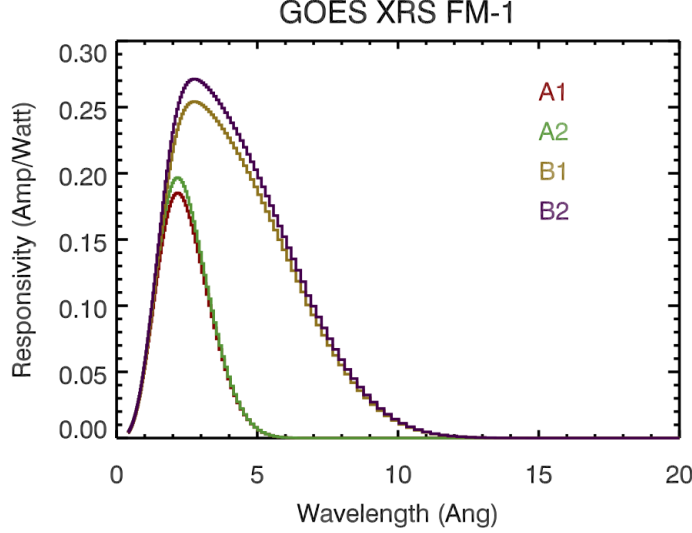


Figure 1: Response functions for the GOES-16 XRS channels.

3 1-second Irradiances Product

This product provides the XRS irradiances for the -A and -B channels along with a condensed set of quality flags. Values are provided for each detector (e.g., XRS-B1) and for the selected primary detectors (e.g., XRS-B). Additional variables include corrected currents for XRS-A2 and -B2, the roll angle, and a yaw flip flag. Particle spikes, probably due to galactic cosmic rays, are flagged in the data.

Status flags are listed in Table 2.

Table 2: Status Flags for 1-sec data

Flag	Description
good_data	no other flags set
eclipse	Earth eclipse or lunar transit
pointing_degraded	$0.11^\circ < \text{pointing error} < 0.4^\circ$
particle_spike	particle spike
calibration	in flight calibration
off_point	satellite off-pointed
temperature_error	XRS temperature out of range
data_quality_error	signal too low/high or non-nominal condition
pointing_error	pointing uncalibrated or pointing error $> 0.4^\circ$; yaw flip in progress
invalid_mode	invalid L1b flags
missing_data	missing data
L0_error	L0 checksum error

Spikes are flagged with a simple equation with two terms which compare the signal to (1) the current median irradiance and (2) the noise level for the past hour. For irradiance, I , a spike is defined as when

$$I_{flat} > 0.01 \cdot I + 1.05 \cdot noise \quad (1)$$

where the flattened irradiance, $I_{flat} = I - median_{5\text{-point}}(I)$ and $noise = \min(|noise_{1hour}|, |noise_{thresh}|)$. Here $noise_{1hour}$ is the lowest value (< 0) in I_{flat} during the previous hour, and $noise_{thresh}$ is the static quiet time minimum determined over a long term. The flux term has an impact at high fluxes and ensures that spikes are significant at high fluxes. The noise term has an impact at low fluxes and during SEP events.

This technique accounts for the fact that the signal has a relatively flat noise component which increases only when there is an SEP event.

4 1-minute Averages Product

This product contains the 1-minute averages of the 1-s cadence data. Data is flagged as good when it is not in an eclipse, does not have degraded pointing or have the bad data flag set. Status flags are listed in Table 3. The union of flags for data that were excluded from the averages is also provided with the data.

Table 3: Status Flags for 1-min averages

Flag	Description
good_data	none of eclipse, pointing_degraded or bad data flags are set
eclipse	Earth eclipse or lunar transit
pointing_degraded	$0.11^\circ < \text{pointing error} < 0.4^\circ$
bad_data	large pointing error ($> 0.4^\circ$), missing data, or otherwise bad data
electron_correction_valid	valid electron correction
electron_correction_invalid	invalid electron correction
electron_correction_interp	electron correction is interpolated
electron_correction_decay	electron correction is a decaying function

Electron contamination is removed in the L2 1-min-averaged data with the use of the GOES-R SEISS MPS-HI measurements of electron flux as a function of angle and energy (Boudouridis et al., 2020). Three X-ray irradiance values are reported for each channel: the averaged flux (e.g., `xrsb_flux_observed`), the estimated electron contamination (e.g., `xrsb_flux_electrons`), and irradiance corrected for the electron contamination (e.g., `xrsb_flux`). The averaged irradiance is constrained above a minimum threshold of 10^{-9} W m^{-2} .

The method for doing the electron contamination removal is currently being updated. More information and figures will be included here at a later point.

There are four flags for the electron correction and one and only one of these flags is set at any one time. When there are missing SEISS electron measurements in the retrospective data, the correction factor is interpolated for gaps less than one hour and the `electron_correction_interp` flag is set. For missing data in real time or gaps longer than one hour in retrospective data, the correction is a decaying function as shown in Figure 2. The `electron_correction_decay` flag is set, but after 60 minutes of decay, it the `electron_correction_invalid` flag is set instead, even as the decay continues.

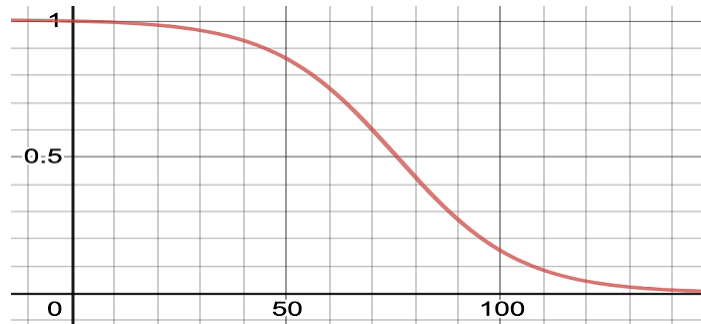


Figure 2: Decaying function applied to the electron contamination for gaps of greater than 1 hour. The decay function is $1.005/(1 + 0.005 \cdot e^{0.07 \cdot t})$ which is a logistic decay for time, t , in minutes.

5 Flare Summary and Flare Detection Products

The flare summary and detection products provide information on flares, including flare class, start and end times, integrated flux, and background flux based on 1-minute cadence XRS-B irradiances. The flare

detection algorithm provides output every minute while the flare summary provides records only for the four most important states. The flare summary files can have a number of practical and scientific applications, such as determining the total energy input to the ionosphere’s D-region. Table 4 shows the available status flags for the two products.

Table 4: Status Flags for Flare Summary and Flare Detection Products

Flag	Description	Summary	Detection
MONITORING	There is no event in progress.		X
EVENT_START	A flare has just started.	X	X
EVENT_RISE	Flare has started but not reached its maximum.		X
EVENT_PEAK	Flare maximum.	X	X
EVENT_DECLINE	Flare has begun to decay.		X
EVENT_END	Flare has declined to 1/2 of flare maximum.	X	X
POST_EVENT	Flare declined to background.	X	X
IMPAIRED	Algorithm has insufficient data to determine status.		X

For most users, the flare summary product should be used and the flare detection product should not be used. The flare summary provides true time stamps for events. The flare detection algorithm must detect X-ray flares in real-time operations. The flare detection time stamps represent the time *when the algorithm detected an event*, such as the flare peak, rather than when the actual peak occurred. For some event types such flare peak, this results in flare detection time stamps that are delayed by several minutes. The flare detection product is used in real-time forecast operations, where minute-to-minute status information is the priority and also provides the input triggers to three other GOES-R L2 algorithms: XRS Flare Location, SUVI Bright Regions and SUVI Flare Location. The flare detection product is provided retrospectively for users who wish to examine the algorithm behavior.

Figure 3 illustrates how the status flags are applied and the differences between the flare summary and flare detection time stamps. Details of the flare detection algorithm are provided in Appendix A.

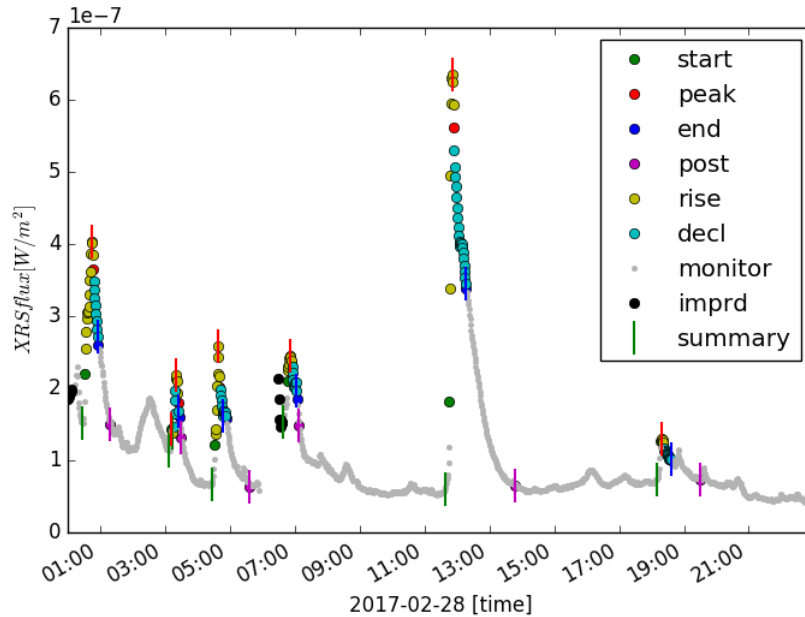


Figure 3: X-ray irradiance from GOES-16 on 28 February 2017. The dots color coded for the flare detection status at each minute. The vertical lines, with the same color codes, are at the actual event times as provided in the flare summary product. The EVENT_START and EVENT_PEAK true times (green and red vertical bars) occur prior to the detection of those event (green and red circles).

6 Flare Location Product

Flare location is determined based on the measurements from the high flux XRS-A2 and -B2 quad diode detectors (Chamberlin et al., 2009). This product is currently being validated and more information and figures will be included here at a later point.

7 Daily Background Product

This product provides daily average irradiances and daily backgrounds for XRS-A and -B. The algorithm uses hourly and 8-hour minima of the 1-minute averages to determine the daily background values.

The algorithm is designed to be consistent with the logic from the former GOES XRS daily background algorithm originally developed by Dave Bouwer in 1981. Using the observation that most major X-ray flares last at most about 8 hours, and that the algorithm is most applicable in describing mid-to-long-term coronal variations on time scales of weeks to years, an approximation of coronal background variations for statistical time series comparisons to other solar indices (e.g., the F10.7 2800-Mhz measurement) could be useful in describing solar active region evolution and the solar cycle. An example of the daily background product is shown in Figure 4. The details of the daily background algorithm are given in Appendix B.

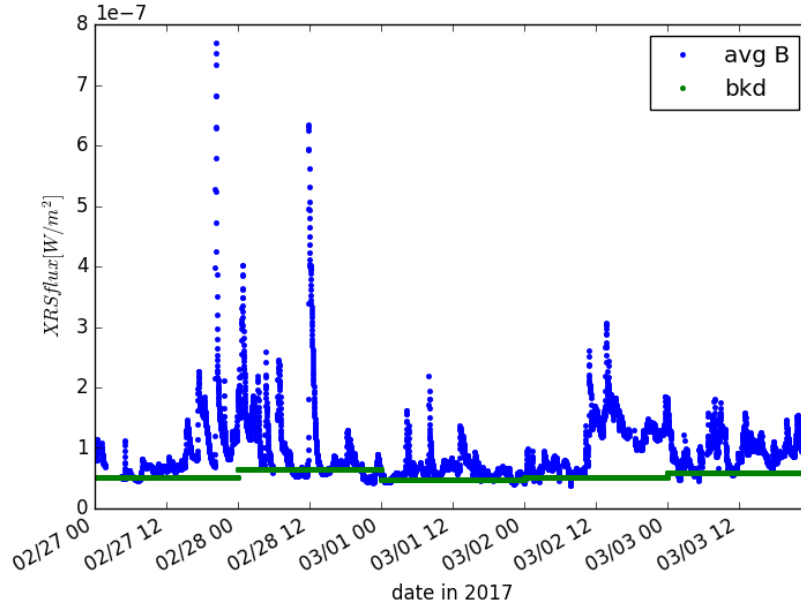


Figure 4: Daily background (green) and 1 minute XRS averages (blue) over 5 days.

8 Plots

Monthly summary plots are provide for both the science-quality and operational 1-minute averaged data. The files contain plots for each of the four detectors (A1, B1, A2, and B2). Traces are shown for the observed and electron-corrected irradiances as well as the estimated electron contamination. An example of the summary plots is shown in Figure 5 for September 2017, a period with X-class flares.



Figure 5: Example monthly summary plot showing X-class flares in GOES-16 XRS science-quality data for September 2017.

9 Acknowledgements

We thank the following people for their work on the development of the initial theoretical algorithm basis documents for the L2 algorithms:

1-s Fluxes: S. D. Bouwer¹, D. Woodraska², T. Woods², F. Eparvier², K. Tobiska¹
Flare Detection: S. D. Bouwer¹, D. Woodraska², S. Mueller², T. Woods², F. Eparvier²,
K. Tobiska¹
Daily Background: S. D. Bouwer¹, D. Woodraska², T. Woods², F. Eparvier², K. Tobiska¹
Flare Location: A. Reinard^{3, 4}

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³ Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder

⁴ NOAA Space Weather Prediction Center, Boulder

We also thank Tom Woods and Don Woodraska for the responsivity values, plots, and code. We thank Tom Eden and Rodney Viereck for algorithm discussions.

10 References

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Appendix A Flare Detection Algorithm

A.1 Flare Detection Algorithm

One of the challenges in developing the event detection algorithm was mitigating the effects of signal noise which can result in false-positives or inaccurate identification of the flare peak or end. Because the block of data examined each moment ("data-frame") is small (generally less than ten points of 1-minute data so as not to include multiple flares), accurate statistics are difficult to achieve. In most cases, the algorithm uses a variety of criteria including an exponential fit to determine that a flare has begun. Figure 6 shows the irradiance during a flare in the first figure and the second derivative in the second figure. The start of the flare is before the inflection point as the irradiance rises. On the rising edge, the inflection point is at the maximum of the first derivative and a zero of the second derivative. For an increasing slope, the second derivative peaks just prior to the inflection point.

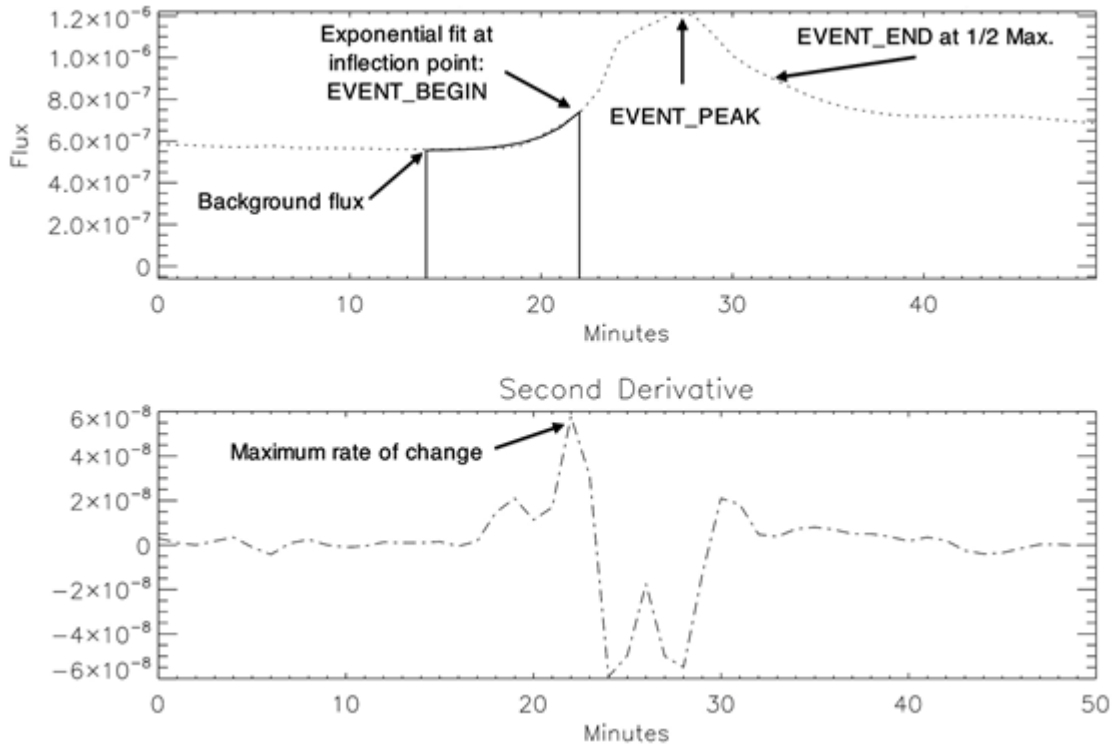


Figure 6: Exponential fit for flare detection algorithm.

The recent background flux level is used both for the exponential fit for the flare rise and for determining the flare end. The best choice for the background can be difficult to select; for example, an hourly average or a shorter time interval could be used to estimate a background. Also, significant signal noise or rapidly repeating flares can result in a too high background estimate, significantly hindering the ability of an algorithm to detect or characterize a flare. By fitting an exponential model to the initial rise of a flare, and using its minimum value, a more accurate background can be estimated that is less susceptible to rapid flaring or signal noise. However, this background can still be in error by up to about $\pm 20\%$ in cases where the pre-flare data has significant signal noise or the flare rises to its peak in several minutes.

Figure 7 presents a flow chart outlining the sequence of operations for the algorithm. Fill values are used whenever a calculation cannot be performed due to missing data. Section A.2 presents the algorithm steps.

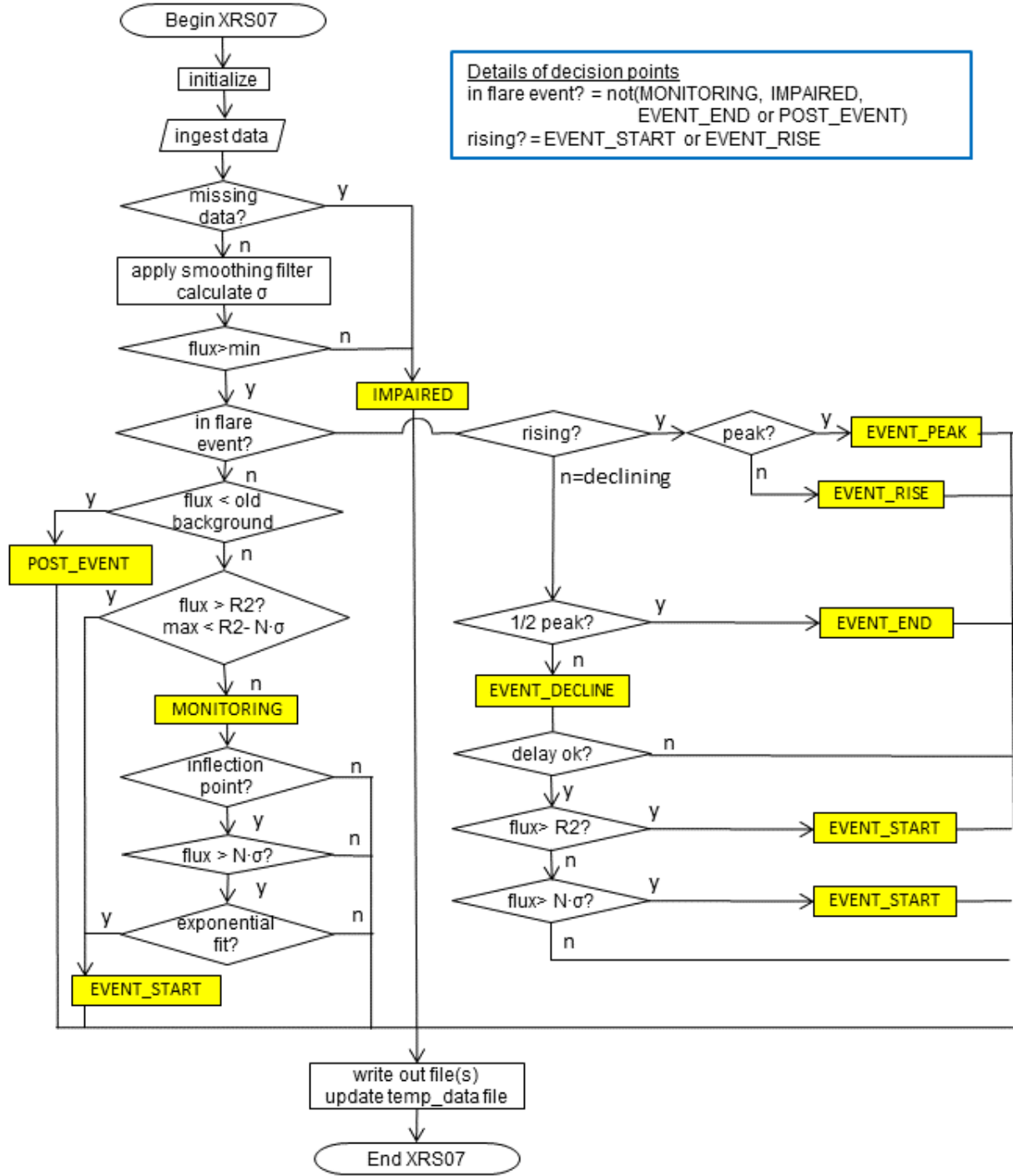


Figure 7: Flowchart of flare detection algorithm. Yellow boxes represent flags.

A.2 Algorithm Steps

The following sections describe the steps in the algorithm. The algorithm inputs and processing variables are defined in Section A.3.

A.2.1 (Steps 1-6) Prepare data and do simple comparisons

1. **Read** next 1-minute data point with *flux* and *curr_time*. **Initialize** variables as needed.
2. Set *prev_status* = **IMPAIRED** and all fluxes to *bad_flux*.
3. **Read** in recent data and current parameters.
4. Create the real time "raw data frame" of raw fluxes, X_i , numbered from 0 to $N-1$, where $N = \text{frame_mins}$. Put most recent flux in the final element of frame. Transfer fluxes from the previous frame into the current frame, leaving the last element available for the new data point. Any gaps in time or differences in array length will result in those elements in the current frame filled with *bad_flux*.
5. If there is any *bad_flux* in the frame, then set *status* = **IMPAIRED** and proceed to "Final steps".
6. For raw fluxes X_i where i is in the first $N-2$ values, **calculate the standard_dev** as

$$\sigma = \sqrt{\sum_i (\bar{X} - X_i)^2 / \bar{X}}$$

where \bar{X} is the mean. Also, **smooth** the full data frame with a small, simple boxcar filter over *n_smooth* points to mitigate noise and reduce false positives. This produces a new data frame of x_0 to x_{n-1} , where the number of elements is $n = N - (n_smooth - 1)$. Typically a 3-minute window is adequate. To simplify timing, the filter width should be an odd number.

7. If $x_{n-1} < \text{min_flux_good}$ then set *status* = **IMPAIRED** and proceed to "Final steps".

A.2.2 (Steps 8a-f) Check for start of flare

At this point, there is a full frame of good data. If the status is not currently in a flare, then the following steps are followed to check if there is a start of a flare. The status is already in a flare event if *prev_status* = *not*(**MONITORING**, **IMPAIRED**, **EVENT_END** or **POST_EVENT**).

8. If *prev_status* did not indicate a flare event, then proceed through Steps a-j.
 - a. If $x_{n-1} < \text{background}$ then set *status* = **POST_EVENT**, set *background* = -999.0, and proceed to "Final steps". The background value is set low to ensure that **POST_EVENT** is only set once.
 - b. If **flux is high** and previously points were low, i.e., $(X_{n-1} > \text{high_flux})$ AND $\max([X_0, \dots, X_{n-2}]) < (R2 - \text{min_num_std} \cdot \sigma)$, then set *status* = **EVENT_START**, set the pre-flare background to the minimum smoothed flux in frame and proceed to "Final steps".
 - c. Set *status* = **MONITORING**.
 - d. If the flux is inadequate for an inflection point, $x_{n-1} < \text{min_inflection_flux}$, then proceed to "Final steps".
 - e. If an **inflection point** has not been reached in the slope of the data frame using the second derivative of the data frame, then proceed to "Final steps". The inflection point is at $\max(d^2x/dt^2)$. To know that this is the inflection point, and not just part of an increasing slope, requires that this point not be the final point within the frame; so, this routines checks the penultimate second derivative. With n time steps of 1 minute (i.e., $dt = 1$), there are $n - 1$ first derivatives in the data frame and $n - 2$ second derivatives which we calculate as $dx_i = x_{i+1} - x_i$, for $i = 0$ to $n - 1$ and $d^2x_j = dx_j - dx_{j-1}$, for $j = 0$ to $n - 2$.
 - f. If flux data has not risen by at least a minimum number of **standard deviation**, then proceed to "Final steps". Calculate the difference in the mean of the first 3 data points versus the mean of the last 3 data values in the frame. There is a potential flare if

$$x_{n-1} - x_0 > \text{min_num_std} \cdot \sigma. \quad (2)$$

g. Fit to an **exponential function**. The fit for the impulsive rise of the flare is to the function:

$$\Phi_{imp}(t) = a \cdot e^{b \cdot t} + c \quad (3)$$

where $t > 0$. Determine the *correlation_coef* and set *temp_background* to minimum of the fitted exponential function (value at $i = 0$).

Proceed to "Final steps" in any of the following cases:

- i. The **rise is inadequate** if $x_{n-1}/temp_background < min_ratio_to_bkd$ or $a < 0$ or $b < 0$.
- ii. The exponential **fit is bad** if $correlation_coef < min_corr_coef$.
- iii. The exponential function is **not increasingly concave** as it should be. The exponential fit determines that the flux is increasing (i.e., $a > 0$ and $b > 0$ in Equation 2), and so in this step it is only necessary to verify that the function is concave. A function is concave if the second derivative is > 0 . The second derivative of Equation 3, is

$$d^2\Phi_{imp}(t)/dt^2 = a \cdot b^2 \cdot e^{b \cdot t}. \quad (4)$$

The fit function is concave when $d^2\Phi_{imp}(t)/dt^2 > 0$; i.e., when $a > 0$.

- iv. The **SNR is not adequate** if the mean of the last 3 points of the exponential function estimate lies a factor less than *min_exp_rise_factor* above the mean of the first 3 data points of the exponential fit.
- h. Set *status* = EVENT_START, set the pre-flare background to *temp_background*, and set *mins_since_event* to the number of minutes (> 0) between the time of the minimum flux and the end of the frame. Proceed to "Final steps".

A.2.3 (Steps 9a-e) Rising flare

- 9. If **flare is rising** (*prev_status* = EVENT_START or EVENT_RISE) then proceed through Steps a-c to look for a peak:
 - a. There was a **flare maximum** if the maximum flux in the last *peak_frame_mins* of the frame is the first point in this peak frame.
 - b. If there was no flare max then, set *status* = EVENT_RISE and proceed to "Final steps".
 - c. In this case, a **flare max** has occurred. Set *status* = EVENT_PEAK, *peak_flux* = maximum flux, *mins_since_peak* = *peak_frame_mins* - 1, and *peak_time* = *curr_time* - *mins_since_peak*. Proceed to "Final steps".

A.2.4 (Steps 10a-b) Declining flare

- 10. If **flare is declining** (*prev_status* = EVENT_PEAK or EVENT_DECLINE) then proceed through Steps a-e to check for a flare end or a new flare start:
 - a. If **end of flare**, then set *status* = EVENT_END and proceed to "Final steps". The event end is defined as when

$$\{median([X_{n-3}, X_{n-2}, X_{n-1}]) - background\} \leq (peak_flux - background)/2. \quad (5)$$

Set *mins_since_event* = *curr_time* - *time_i* for first i where $(X_i - background) \leq (peak_flux - background)/2$.

Note: the POST_EVENT flag is set in Step 8a if $flux < background$.

- b. Set *status* = EVENT_DECLINE
- c. If the elapsed time since the peak is too short to start looking for another flare ($curr_time - peak_time < min_time_after_peak$), then proceed to "Final steps".

- d. If a new flare has begun, then set *status* = EVENT_START, set the pre-flare *background* to the minimum non-smoothed flux since the peak, and set *mins_since_event* = *curr_time* – (time of this minimum flux).

A new flare is indicated if either (1) the **flux is high** ($X_{n-1} > \text{high_flux}$) and *peak_flux* < *high_flux*, or (2) the smoothed flux has risen by at least a minimum number of standard deviations. In the second case, in the subset of the current frame where the time is at least *mins_since_peak* minutes have elapsed since the peak, the index *j* of the minimum flux is found. There is a flare start if:

$$x_{n-1} - x_j > \text{min_num_std} * \sigma. \quad (6)$$

- e. Proceed to "Final steps".

A.2.5 (Steps 11a-e) Final steps to exit

11. Final steps to exit.

- a. If *status* = IMPAIRED or POST_EVENT, then set *background* = *background_reset* so that a subsequent POST_EVENT will not be declared.
b. If *status* = EVENT_START, then

$$\text{integrated_flux}[J/m^2] = \frac{60 \text{ s}}{\text{1-min average}} \cdot \sum_{n-1-\text{mins_since_start}}^{n-1} x_i[W/m^2]. \quad (7)$$

- c. If *status* = EVENT_RISE, EVENT_PEAK, EVENT_DECLINE, or EVENT_END, then add to the integrated flux:

$$\text{integrated_flux}[J/m^2] += \frac{60 \text{ s}}{\text{1-min average}} \cdot x_{n-1}[W/m^2] \quad (8)$$

- d. Write a real time flare detection record with *curr_time*, *status*, and x_{n-1} . Also write out the integrated flux if *status* = EVENT_START, EVENT_RISE, EVENT_PEAK, EVENT_DECLINE, or EVENT_END.
e. Write a flare summary record if *status* = EVENT_START, EVENT_PEAK, EVENT_END, or POST_EVENT.

A.3 Algorithm Inputs

For the flare detection algorithm the input data is the XRS-B fluxes from the L2 1-minute average files (xrsf-l2-avg1m). Some of the configurable inputs for the algorithm are given in Table 5. Some of the variables used within the algorithm are given in Table 6.

Table 5: Configurable inputs for the flare detection algorithm.

Parameter	Description	Example	Units
frame_mins	data frame size	9	mins
high_flux	threshold for expedited flare declaration	5e-5	W/m^2
max_iter_exp_fit	maximum number of iterations	30	—
min_corr_coef	minimum correlation coefficient	0.925	—
min_exp_rise_factor	minimum ration of end of fit to start of fit	1.225	—
min_flux_good	minimum flux threshold below which status is IMPAIRED	1e-9	W/m^2
min_inflection_flux	minimum flux for inflection point to be an EVENT_START	1e-7	W/m^2
min_num_std	minimum number of standard deviations above background	1	—
min_ratio_to_bkgd	minimum ratio to background for event start	1.225	—
min_time_after_peak	minimum time after an event start before next event start	8	mins
n_smooth	size of smoothing window	3	—
peak_frame_mins	size of data frame used to determine event peak	7	—
bad_flux	fill value for bad fluxes	—	—

Table 6: Variables within the flare detection algorithm.

Variable	Description
curr_time	time of current record
prev_status	status of previous minute
status	current status
mins_since_peak	minutes since last EVENT_PEAK
mins_since_event	used for EVENT_START and EVENT_END
background	most recent background flux
background_reset	value < 0 to reset background
peak_flux	most recent peak flux
integrated_flux	integrated since last EVENT_START
standard_dev	standard deviation of n-2 smoothed frame elements
peak_time	time of last peak
event_time	time of last event

Appendix B Daily Background Algorithm

This algorithm creates a daily X-ray background irradiance from the XRS-B 1-minute irradiances. If there is no data to be averaged, then a fill value is output for the irradiances and the flag is set to bad data. Figure 8 presents a flow chart outlining the sequence of operations for the algorithm. Fill values are used whenever a calculation cannot be performed due to missing data.

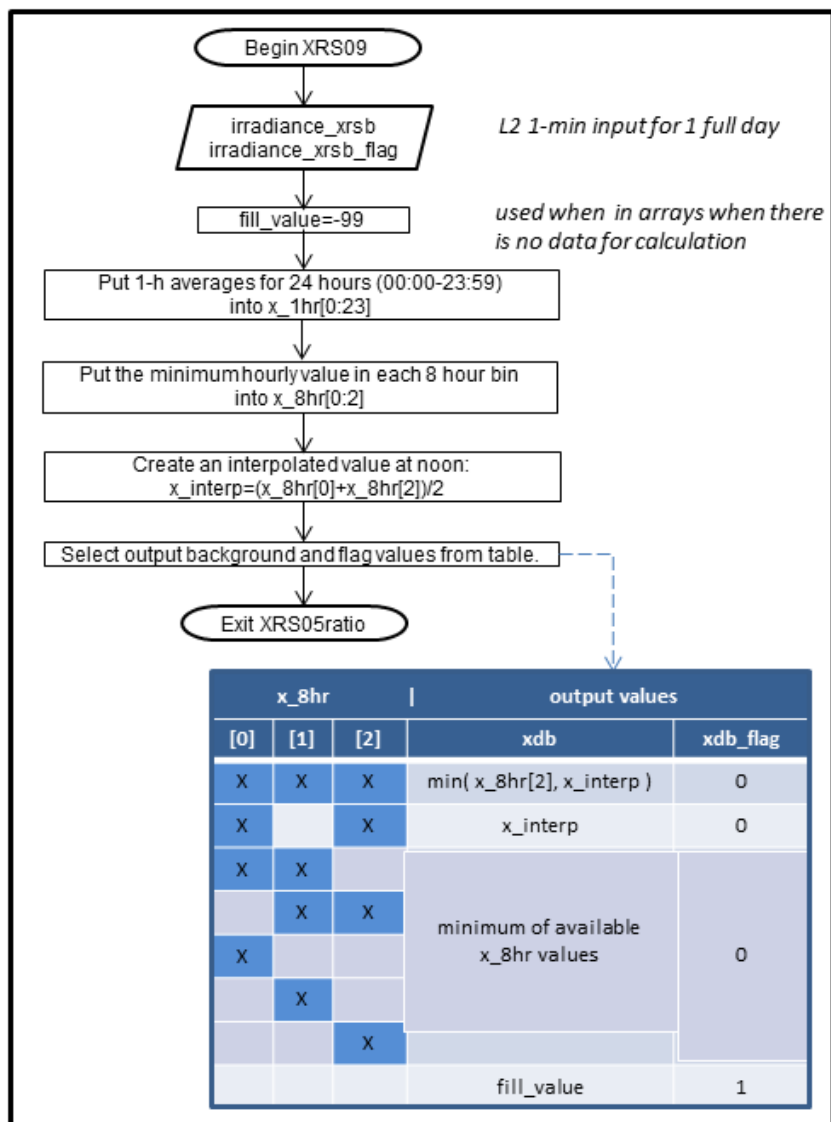


Figure 8: Flowchart of daily background algorithm.

The sequence of operations is:

1. Calculate hourly averages from XRS-B (0.1-0.8 nm) one-minute fluxes if there is at least 1 valid data point for the hour.
2. Divide 24 hourly averages into three equal blocks of 8 hours, x_8hr: e.g., 00-07, 08-15, and 16-23.
3. Calculate the minimum hourly average for each of the 3 blocks.
4. Perform a simple average of the minima of the 2 outer blocks for an interpolated minimum at noon.

5. Set the X-ray daily background (xdb) as the mid-day minimum if at least one of the three bins has good data. Set the xdb_flag=0.
 - a. If all three 8-h blocks have good data, select the lower minimum from either the middle bin or the interpolated noon bin.
 - b. If the middle block has no data, select the interpolated minimum.
 - c. When either the first or third block does not have data, select the lower of the two remaining blocks.
 - d. If only one block has data, use its value.
6. If no blocks have good data, set xdb to the fill value and set the xdb_flag=1 for missing data.